

REMARKS

This Response is a reply to the first (nonfinal) Office Action mailed by the USPTO on November 27, 2000. In the above-identified Office Action, the Official Draftsperson objected to the drawings. The Examiner allowed claims 12-31, 39-42, and 44-50 and objected to claims 2-6, 8-9, and 33-35. The Examiner rejected claims 1, 7, 10-11, 32, and 36-38 under 35 U.S.C. §102(e) and rejected claim 43 under 35 U.S.C. §103(b). Applicant has amended claims 1, 2, 3, 6, 8, 11, 12, 29, 31, 32, 33, 35, 39, 43, and 50. Claims 1-50 remain pending in the Application. No new matter has been added to the Application. Reconsideration of the pending claims is respectfully requested.

Drawings

The Official Draftsperson's objections to the originally-filed drawings have been overcome by the substitute formal drawings enclosed herewith.

Allowed Subject Matter

Applicants note with appreciation the Examiner's allowance of claims 12-31, 39-42, and 44-50. Allowed claims 12, 29, 31, and 39 were amended to delete an unnecessary limitation ("adapted to be arranged in fluid communication with the source of actuating fluid") and to change the reoccurring phrase "air inlet port" to - - air intake port - - for consistent terminology. Allowed claim 50 was amended to correct an obvious error in claim dependency. None of these amendments narrow the scope of each originally-filed claim 12, 29, 31, 39, and 50 for any reason related to the statutory requirements for a patent.

Allowable Subject Matter

Applicants note with appreciation the Examiner's indication of allowable subject matter. The Examiner stated that claims 2-6, 8-9, and 33-35 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Allowed claim 6 was amended to correct an obvious error. The above objections have been overcome by rewriting claim 2 in independent form including the limitations of base claim 1; rewriting claim 3 in independent form including the limitations of base claim 1; rewriting claim 8 in independent form including the limitations of base claim 1; rewriting claim 33 in independent form including the limitations of base claim 32; and rewriting claim 35 in independent form including the limitations of base claim 32. None of these amendments narrow the scope of each originally-filed claim 2, 3, 6, 8, 33, and 35 for any reason related to the statutory requirements for a patent.

Rejection under 35 U.S.C. §102(b)

Claims 1, 7, 10-11, 32, and 36-38 were rejected by the Examiner under 35 U.S.C. §102(e) as being anticipated by U.S. Patent No. 5,857,436 (Chen).

Claim 1 has been amended to better distinguish over Chen and overcome the respective rejection. Unlike the air inlet valve 14 described and illustrated by Chen, amended claim 1 now recites that the air supply valve is electronically-controllable and magnetically-latchable. Dependent claims 7 and 10 depend from amended claim 1.

Claim 11 has been amended to better distinguish over Chen and overcome the respective rejection. Unlike the air inlet valve 14 described and illustrated by Chen, amended claim 11 now

recites that the free air supply valve and the turbocharged air supply valve are each electronically-controllable and magnetically-latchable.

Claim 32 has been amended to better distinguish over Chen and overcome the respective rejection. Unlike the air inlet valve 14 described and illustrated by Chen, amended claim 32 now recites that air supply valve is electronically-controllable and magnetically-latchable. Amended claim 32 further recites that the intake valve is hydraulically actuatable and controlled by an electronically-controllable magnetically-latchable first control valve and that the exhaust valve is hydraulically actuatable and controlled by an electronically-controllable magnetically-latchable second control valve. Dependent claims 36, 37, and 38 depend from amended claim 32.

Rejection under 35 U.S.C. §102(e)

Claim 43 was rejected by the Examiner under 35 U.S.C. §102(b) as being anticipated by U.S. Patent No. 5,237,968 (Miller et al.).

Claim 43 has been amended to better distinguish over Miller et al. and overcome the respective rejection. Unlike the intake valves (4,4'), exhaust valves (6,6'), and fuel injection system (8) that are controlled by a single piezoelectric motor (18) as described and illustrated by Miller et al., amended claim 43 now recites that i) the intake valve is hydraulically actuatable and controlled by an electronically-controllable magnetically-latchable first control valve, ii) the exhaust valve is hydraulically actuatable and controlled by an electronically-controllable magnetically-latchable second control valve, and iii) the fuel injector is hydraulically actuatable and controlled by an electronically-controllable magnetically-latchable third control valve.

Claims

I claim:

1. (Amended) A power module, comprising:

an air compressor cell defining a variable-volume air compressor chamber, an air supply port, and an air exit port, said air supply port and air exit port each arranged in fluid communication with the air compressor chamber, said air supply port adapted to communicate with a source of supply air;

an electronically-controllable magnetically-latchable air supply valve associated with the air supply port and selectively operable to move between i) a closed position at which the air supply valve closes the air supply port and thereby closes fluid communication between the source of supply air and the air compressor chamber via the air supply port and ii) an opened position at which the air supply valve opens the air supply port and thereby opens fluid communication between the source of supply air and the air compressor chamber via the air supply port;

an air pump piston positioned in the air compressor chamber and operable to move between i) an expansion position at which the air compressor chamber reaches its maximum volume and ii) a contraction position at which the air compressor chamber reaches its minimum volume;

a combustion cell defining a variable-volume combustion chamber separate from the air compressor chamber, an air intake port, and an exhaust port, said air intake port and exhaust port each arranged in fluid communication with the combustion chamber;

an air storage chamber arranged in fluid communication between the air exit port of the air compressor cell and the air intake port of the combustion cell;

an intake valve associated with the air intake port of the combustion cell and selectively operable to move between i) a closed position at which the intake valve closes the air intake port and thereby closes fluid communication between the air storage chamber and the combustion chamber via the air intake port and ii) an opened position at which the intake valve opens the air intake port and thereby opens fluid communication between the air storage chamber and the combustion chamber via the air intake port;

an exhaust valve associated with the exhaust port of the combustion cell and selectively operable to move between i) a closed position at which the exhaust valve closes the exhaust port and thereby closes fluid communication between the combustion chamber and the exhaust port and ii) an opened position at which the exhaust valve opens the exhaust port and thereby opens fluid communication between the combustion chamber and the exhaust port; and

a power piston positioned in the combustion chamber and operable to move therein between i) an expansion position at which the combustion chamber reaches its maximum volume and ii) a contraction position at which the combustion chamber reaches its minimum volume.

2. [The power module of claim 1](Amended) A power module, comprising:

an air compressor cell defining a variable-volume air compressor chamber, an air supply port, and an air exit port, said air supply port and air exit port each arranged in fluid communication with the air compressor chamber, said air supply port adapted to communicate with a source of supply air;

an air supply valve associated with the air supply port and selectively operable to move between i) a closed position at which the air supply valve closes the air supply port and thereby closes fluid communication between the source of supply air and the air compressor chamber via the air supply port and ii) an opened position at which the air supply valve opens the air supply port and thereby opens fluid communication between the source of supply air and the air compressor chamber via the air supply port;

an air pump piston positioned in the air compressor chamber and operable to move between i) an expansion position at which the air compressor chamber reaches its maximum volume and ii) a contraction position at which the air compressor chamber reaches its minimum volume;

a combustion cell defining a variable-volume combustion chamber separate from the air compressor chamber, an air intake port, and an exhaust port, said air intake port and exhaust port each arranged in fluid communication with the combustion chamber;

22 an air storage chamber arranged in fluid communication between the air exit
23 port of the air compressor cell and the air intake port of the combustion cell;

24 an intake valve associated with the air intake port of the combustion cell and
25 selectively operable to move between i) a closed position at which the intake valve
26 closes the air intake port and thereby closes fluid communication between the air
27 storage chamber and the combustion chamber via the air intake port and ii) an
28 opened position at which the intake valve opens the air intake port and thereby opens
29 fluid communication between the air storage chamber and the combustion chamber
30 via the air intake port;

31 an exhaust valve associated with the exhaust port of the combustion cell and
32 selectively operable to move between i) a closed position at which the exhaust valve
33 closes the exhaust port and thereby closes fluid communication between the
34 combustion chamber and the exhaust port and ii) an opened position at which the
35 exhaust valve opens the exhaust port and thereby opens fluid communication
36 between the combustion chamber and the exhaust port; and

37 a power piston positioned in the combustion chamber and operable to move
38 therein between i) an expansion position at which the combustion chamber reaches
39 its maximum volume and ii) a contraction position at which the combustion chamber
40 reaches its minimum volume, further including an air check valve arranged in fluid
41 communication between said air exit port of the air compressor cell and the air
42 storage chamber, said air check valve operable to allow only one-way fluid flow
43 from the air compressor chamber to the air storage chamber.

44
1 3. [The power module of claim 1](Amended) A power module,
2 comprising:

3 an air compressor cell defining a variable-volume air compressor chamber,
4 an air supply port, and an air exit port, said air supply port and air exit port each
5 arranged in fluid communication with the air compressor chamber, said air supply
6 port adapted to communicate with a source of supply air;

7 an air supply valve associated with the air supply port and selectively
8 operable to move between i) a closed position at which the air supply valve closes
9 the air supply port and thereby closes fluid communication between the source of

supply air and the air compressor chamber via the air supply port and ii) an opened position at which the air supply valve opens the air supply port and thereby opens fluid communication between the source of supply air and the air compressor chamber via the air supply port;

an air pump piston positioned in the air compressor chamber and operable to move between i) an expansion position at which the air compressor chamber reaches its maximum volume and ii) a contraction position at which the air compressor chamber reaches its minimum volume;

a combustion cell defining a variable-volume combustion chamber separate from the air compressor chamber, an air intake port, and an exhaust port, said air intake port and exhaust port each arranged in fluid communication with the combustion chamber;

an air storage chamber arranged in fluid communication between the air exit port of the air compressor cell and the air intake port of the combustion cell;

an intake valve associated with the air intake port of the combustion cell and selectively operable to move between i) a closed position at which the intake valve closes the air intake port and thereby closes fluid communication between the air storage chamber and the combustion chamber via the air intake port and ii) an opened position at which the intake valve opens the air intake port and thereby opens fluid communication between the air storage chamber and the combustion chamber via the air intake port;

an exhaust valve associated with the exhaust port of the combustion cell and selectively operable to move between i) a closed position at which the exhaust valve closes the exhaust port and thereby closes fluid communication between the combustion chamber and the exhaust port and ii) an opened position at which the exhaust valve opens the exhaust port and thereby opens fluid communication between the combustion chamber and the exhaust port; and

a power piston positioned in the combustion chamber and operable to move therein between i) an expansion position at which the combustion chamber reaches its maximum volume and ii) a contraction position at which the combustion chamber reaches its minimum volume, wherein said air supply valve is [a]an

41 electronically-controllable two-way valve including a movable magnetically-
42 latchable poppet having an end portion, a return spring operable to bias the poppet
43 towards one position corresponding to the closed position of the air supply valve,
44 and an opening-direction electrical coil located proximate the end portion of the
45 poppet, said opening-direction electrical coil selectively operable to
46 electromagnetically pull the poppet towards another position corresponding to the
47 opened position of the air supply valve.

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1 4. The power module of claim 3, further including an electronic control
2 unit operable to selectively and independently control the operation of the air supply
3 valve with digital pulses of electrical current.

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1 5. The power module of claim 4, further including an air pressure sensor
2 operable to sense the pressure of air in the air storage chamber and provide the
3 electronic control unit with a signal indicative of such pressure, said electronic
4 control unit operable to move the air supply valve to its opened position in response
5 to said pressure being below a threshold air pressure, said electronic control unit
6 operable to move the air supply valve to its closed position in response to said
7 pressure being at least the threshold air pressure.

8
1 6. (Amended) The [internal combustion]power module of claim 5,
2 wherein the control unit is operable to selectively and independently control the
3 operation of the air supply valve in further response to at least one sensed parameter
4 selected from the group of ambient air temperature, ambient barometric pressure,
5 inlet air temperature, inlet air pressure, actuating fluid temperature, actuating fluid
6 pressure, throttle position, power piston position, engine brake signals, starter inputs,
7 and ignition switch position.

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1 7. The power module of claim 1, wherein the air compressor cell and
2 the combustion cell are integrally formed adjacent one another by a common
3 housing.

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1 8. [The power module of claim 1](Amended) A power module,
2 comprising:

3 an air compressor cell defining a variable-volume air compressor chamber,
4 an air supply port, and an air exit port, said air supply port and air exit port each
5 arranged in fluid communication with the air compressor chamber, said air supply
6 port adapted to communicate with a source of supply air;

7 an air supply valve associated with the air supply port and selectively
8 operable to move between i) a closed position at which the air supply valve closes
9 the air supply port and thereby closes fluid communication between the source of
10 supply air and the air compressor chamber via the air supply port and ii) an opened
11 position at which the air supply valve opens the air supply port and thereby opens
12 fluid communication between the source of supply air and the air compressor
13 chamber via the air supply port;

14 an air pump piston positioned in the air compressor chamber and operable to
15 move between i) an expansion position at which the air compressor chamber reaches
16 its maximum volume and ii) a contraction position at which the air compressor
17 chamber reaches its minimum volume;

18 a combustion cell defining a variable-volume combustion chamber separate
19 from the air compressor chamber, an air intake port, and an exhaust port, said air
20 intake port and exhaust port each arranged in fluid communication with the
21 combustion chamber;

22 an air storage chamber arranged in fluid communication between the air exit
23 port of the air compressor cell and the air intake port of the combustion cell;

24 an intake valve associated with the air intake port of the combustion cell and
25 selectively operable to move between i) a closed position at which the intake valve
26 closes the air intake port and thereby closes fluid communication between the air
27 storage chamber and the combustion chamber via the air intake port and ii) an
28 opened position at which the intake valve opens the air intake port and thereby opens
29 fluid communication between the air storage chamber and the combustion chamber
30 via the air intake port;

31 an exhaust valve associated with the exhaust port of the combustion cell and
32 selectively operable to move between i) a closed position at which the exhaust valve

33 closes the exhaust port and thereby closes fluid communication between the
34 combustion chamber and the exhaust port and ii) an opened position at which the
35 exhaust valve opens the exhaust port and thereby opens fluid communication
36 between the combustion chamber and the exhaust port; and
37 a power piston positioned in the combustion chamber and operable to move
38 therein between i) an expansion position at which the combustion chamber reaches
39 its maximum volume and ii) a contraction position at which the combustion chamber
40 reaches its minimum volume, wherein the air pump piston and the power piston are
41 movable by a common drive device.

42
1 9. The power module of claim 8, wherein said common drive device
2 includes a rotatable crankshaft.

3
1 10. The power module of claim 1, further including a direct-injection fuel
2 injector extending into the combustion chamber and selectively operable to inject
3 fuel therein.

4
1 11. (Amended) A power module, comprising:
2 a turbocharger including an exhaust gas inlet and a compressed air outlet;
3 an air compressor cell defining a variable-volume air compressor chamber, a
4 free air supply port adapted to communicate with atmosphere, at least one
5 turbocharged air supply port arranged in fluid communication with the compressed
6 air outlet of the turbocharger, and an air exit port, said free air supply port,
7 turbocharged air supply port, and air exit port each arranged in separate fluid
8 communication with the air compressor chamber;
9 [a]an electronically-controllable magnetically-latchable free air supply valve
10 associated with the free air supply port and selectively operable to move between i) a
11 closed position at which the air supply valve closes the air supply port and thereby
12 closes fluid communication between atmosphere and the air compressor chamber via
13 the free air supply port and ii) an opened position at which the free air supply valve
14 opens the free air supply port and thereby opens fluid communication between
15 atmosphere and the air compressor chamber via the free air supply port;

16 [a]an electronically-controllable magnetically-latchable turbocharged air
17 supply valve associated with each turbocharged air supply port and selectively
18 operable to move between i) a closed position at which the turbocharged air supply
19 valve closes its respective turbocharged air supply port and thereby closes fluid
20 communication between the compressed air outlet of the turbocharger and the air
21 compressor chamber via the respective turbocharged air supply port and ii) an
22 opened position at which the turbocharged air supply valve opens its respective
23 turbocharged air supply port and thereby opens fluid communication between the
24 compressed air outlet of the turbocharger and the air compressor chamber via the
25 respective turbocharged air supply port;

26 an air pump piston positioned in the air compressor chamber and operable to
27 move between i) an expansion position at which the air compressor chamber reaches
28 its maximum volume and ii) a contraction position at which the air compressor
29 chamber reaches its minimum volume;

30 a combustion cell defining a variable-volume combustion chamber separate
31 from the air compressor chamber, an air intake port, a free exhaust port adapted to
32 communicate with atmosphere, and at least one drive exhaust port arranged in fluid
33 communication with the exhaust gas inlet of the turbocharger, said air intake port,
34 free exhaust port, and drive exhaust port each arranged in separate fluid
35 communication with the combustion chamber;

36 an air storage chamber arranged in fluid communication between the air exit
37 port of the air compressor cell and the air intake port of the combustion cell;

38 an intake valve associated with the air intake port of the combustion cell and
39 selectively operable to move between i) a closed position at which the intake valve
40 closes the air intake port and thereby closes fluid communication between the air
41 storage chamber and the combustion chamber via the air intake port and ii) an
42 opened position at which the intake valve opens the air intake port and thereby opens
43 fluid communication between the air storage chamber and the combustion chamber
44 via the air intake port;

45 a free exhaust valve associated with the free exhaust port of the combustion
46 cell and selectively operable to move between i) a closed position at which the free
47 exhaust valve closes the free exhaust port and thereby closes fluid communication

between the combustion chamber and atmosphere via the free exhaust port and ii) an opened position at which the free exhaust valve opens the free exhaust port and thereby opens fluid communication between the combustion chamber and atmosphere via the free exhaust port;

a drive exhaust valve associated with each drive exhaust port of the combustion cell and selectively operable to move between i) a closed position at which the drive exhaust valve closes its respective drive exhaust port and thereby closes fluid communication between the combustion chamber and the exhaust gas inlet of the turbocharger via the respective drive exhaust port and ii) an opened position at which the drive exhaust valve opens its respective drive exhaust port and thereby opens fluid communication between the combustion chamber and the exhaust gas inlet of the turbocharger via the respective drive exhaust port; and

a power piston positioned in the combustion chamber and operable to move therein between i) an expansion position at which the combustion chamber reaches its maximum volume and ii) a contraction position at which the combustion chamber reaches its minimum volume.

12. (Amended) A power module, comprising:

an actuating fluid compressor cell defining a variable-volume actuating fluid compressor chamber and an actuating fluid port arranged in fluid communication with the actuating fluid compressor chamber, said actuating fluid port adapted to communicate with a source of actuating fluid;

an actuating fluid drain passage [adapted to be arranged in fluid communication with the source of actuating fluid];

an actuating fluid supply valve arranged in fluid communication between the source of actuating fluid and the actuating fluid port and selectively operable to move between i) a closed position at which the supply valve closes fluid communication between the source of actuating fluid and the actuating fluid compressor chamber via the actuating fluid port and ii) an opened position at which the supply valve opens fluid communication between the source of actuating fluid and the actuating fluid compressor chamber via the actuating fluid port;

15 an actuating fluid pump piston positioned in the actuating fluid compressor
16 chamber and operable to move therein between i) an expansion position at which
17 the actuating fluid compressor chamber reaches its maximum volume and ii) a
18 contraction position at which the actuating fluid compressor chamber reaches its
19 minimum volume;

20 a combustion cell defining a variable-volume combustion chamber, separate
21 from the actuating fluid compressor chamber, an air [inlet]intake port, an exhaust
22 port, and an actuating fluid common rail, said air [inlet]intake port and exhaust port
23 each arranged in fluid communication with the combustion chamber;

24 an actuating fluid storage chamber arranged in fluid communication between
25 the actuating fluid port of the actuating fluid compressor cell and the actuating fluid
26 common rail;

27 a hydraulically-actuatable intake valve associated with the air [inlet]intake
28 port of the combustion cell and having an actuating fluid chamber and a piston
29 portion positioned in the actuating fluid chamber, said intake valve selectively
30 operable to move between i) a closed position at which the intake valve closes the air
31 [inlet]intake port and thereby closes fluid communication to the combustion
32 chamber via the air [inlet]intake port and ii) an opened position at which the intake
33 valve opens the air [inlet]intake port and thereby opens fluid communication to the
34 combustion chamber via the air [inlet]intake port;

35 an electronically-controllable magnetically-latchable first control valve
36 arranged in fluid communication between the actuating fluid common rail and the
37 actuating fluid chamber of the intake valve, said first control valve selectively
38 operable to move between i) a closed position at which the first control valve closes
39 fluid communication between the actuating fluid common rail and the actuating fluid
40 chamber of the intake valve and opens fluid communication between the actuating
41 fluid drain passage and the actuating fluid chamber of the intake valve thereby
42 allowing the intake valve to be moved towards its closed position and ii) an opened
43 position at which the first control valve opens fluid communication between the
44 actuating fluid common rail and the actuating fluid chamber of the intake valve and
45 closes fluid communication between the actuating fluid drain passage and the

46 actuating fluid chamber of the intake valve thereby allowing the intake valve to be
47 hydraulically moved towards its opened position ;

48 a hydraulically-actuatable exhaust valve associated with the exhaust port of
49 the combustion cell and having an actuating fluid chamber and a piston portion
50 positioned in the actuating fluid chamber, said exhaust valve selectively operable to
51 move between i) a closed position at which the exhaust valve closes the exhaust port
52 and thereby closes fluid communication between the combustion chamber and the
53 exhaust port and ii) an opened position at which the exhaust valve opens the exhaust
54 port and thereby opens fluid communication between the combustion chamber and
55 the exhaust port;

56 an electronically-controllable magnetically-latchable second control valve
57 arranged in fluid communication between the actuating fluid common rail and the
58 actuating fluid chamber of the exhaust valve, said second control valve selectively
59 operable to move between i) a closed position at which the second control valve
60 closes fluid communication between the actuating fluid common rail and the
61 actuating fluid chamber of the exhaust valve and opens fluid communication
62 between the actuating fluid drain passage and the actuating fluid chamber of the
63 exhaust valve thereby allowing the exhaust valve to be moved towards its closed
64 position and ii) an opened position at which the second control valve opens fluid
65 communication between the actuating fluid common rail and the actuating fluid
66 chamber of the exhaust valve and closes fluid communication between the actuating
67 fluid drain passage and the actuating fluid chamber of the exhaust valve thereby
68 allowing the exhaust valve to be hydraulically moved towards its opened position;
69 and

70 a power piston positioned in the combustion chamber and operable to move
71 therein between i) an expansion position at which the combustion chamber reaches
72 its maximum volume and ii) a contraction position at which the combustion chamber
73 reaches its minimum volume.

74
1 13. The power module of claim 12, further including a check valve
2 arranged in fluid communication between the actuating fluid port of the actuating
3 fluid compressor cell and the actuating fluid storage chamber, said check valve

operable to allow only one-way fluid flow from the actuating fluid compressor chamber to the actuating fluid storage chamber.

14. The power module of claim 12, wherein said actuating fluid supply valve includes a digitally-controlled two-way valve including a movable magnetically-latchable spool having one end portion and an opposite end portion, a closing-direction electrical coil located proximate the one end portion of the spool, and an opening-direction electrical coil located proximate the opposite end portion of the spool, said closing-direction electrical coil selectively operable to electromagnetically pull the spool towards one state corresponding to the closed position of the actuating fluid supply valve, said opening-direction electrical coil selectively operable to electromagnetically pull the spool towards another state corresponding to the opened position of the actuating fluid supply valve.

15. The power module of claim 12, wherein said first and second control valves each include a digitally-controlled three-way valve including a movable magnetically-latchable spool having one end portion and an opposite end portion, a closing-direction electrical coil located proximate the one end portion of the spool, and an opening-direction electrical coil located proximate the opposite end portion of the spool, said closing-direction electrical coil selectively operable to electromagnetically pull the spool towards one state corresponding to the closed position of the first control valve, said opening-direction electrical coil selectively operable to electromagnetically pull the spool towards another state corresponding to the opened position of the first control valve.

16. The power module of claim 12, further including an electronic control unit operable to control the selectable operation of each said electronically-controllable valves.

17. The power module of claim 16, further including an actuating fluid pressure sensor operable to i) sense the pressure of actuating fluid in the actuating fluid storage chamber and ii) provide the electronic control unit with an actuating

4 fluid pressure signal indicative of said pressure, said electronic control unit operable
5 to independently control the operation of the actuating fluid supply valve in response
6 to said actuating fluid pressure signal.

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1 18. The power module of claim 16, further including an actuating fluid
2 pressure sensor operable to i) sense the pressure of actuating fluid in the actuating
3 fluid common rail and ii) provide the electronic control unit with an actuating fluid
4 pressure signal indicative of said pressure, said electronic control unit operable to
5 independently control the operation of the first and second control valves in response
6 to said actuating fluid pressure signal.

7
1 19. The power module of claim 16, wherein said electronic control unit
2 further independently controls the operation of the first and second control valves in
3 response to at least one sensed parameter selected from the group of ambient air
4 temperature, ambient barometric pressure, inlet air temperature, inlet air pressure,
5 actuating fluid temperature, actuating fluid pressure, throttle position, power piston
6 position, engine brake signals, starter inputs, and ignition switch position.

7
1 20. The power module of claim 12, further including an
2 electronically-controllable hydraulically-actuatable fuel injector extending into the
3 combustion chamber and selectively operable to inject fuel therein.

4
1 21. The power module of claim 20, wherein said injector includes an
2 actuating fluid chamber, a piston portion positioned in the actuating fluid chamber, a
3 check valve movable between a closed position at which the check valve blocks
4 injection of fuel and an opened position at which the check valve opens injection of
5 fuel, and an electronically-controllable magnetically-latchable third control valve
6 arranged in fluid communication between the actuating fluid common rail and the
7 actuating fluid chamber of the injector, said third control valve selectively operable
8 to move between i) a closed position at which the third control valve closes fluid
9 communication between the actuating fluid common rail and the actuating fluid
10 chamber of the injector and opens fluid communication between the actuating fluid

11 drain passage and the actuating fluid chamber of the injector thereby allowing the
12 check valve of the injector to be moved towards its closed position and ii) an opened
13 position at which the third control valve opens fluid communication between the
14 actuating fluid common rail and the actuating fluid chamber of the injector and
15 closes fluid communication between the actuating fluid drain passage and the
16 actuating fluid chamber of the injector thereby allowing the check valve to be
17 hydraulically moved towards its opened position.

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1 22. The power module of claim 21, wherein said injector is a multiple
2 stage injector.

3
1 23. The power module of claim 12, wherein said actuating fluid storage
2 chamber is integrally formed with the actuating fluid compressor cell.

3
1 24. The power module of claim 12, wherein said actuating fluid storage
2 chamber is connected to the actuating fluid compressor cell.

3
1 25. The power module of claim 12, wherein said intake and exhaust
2 valves each further include a return spring operable to bias the respective valve
3 towards its closed position.

4
1 26. The power module of claim 12, wherein the actuating fluid
2 compressor cell and the combustion cell are integrally formed with one another by a
3 common housing.

4
1 27. The power module of claim 12, wherein the actuating fluid
2 compressor cell and the combustion cell are connected together as a compact unit.

3
1 28. The power module of claim 12, wherein the actuating fluid pump
2 piston and the power piston are movable by a common drive device.

3
1 29. (Amended) A power module, comprising:

2 an air compressor cell defining a variable-volume air compressor chamber,
3 an air supply port, and an air exit port, said air supply port and air exit port each
4 arranged in fluid communication with the air compressor chamber, said air supply
5 port adapted to communicate with a source of supply air;

6 an air supply valve associated with the air supply port and selectively
7 operable to move between i) a closed position at which the air supply valve closes
8 the air supply port and thereby closes fluid communication between the source of
9 supply air and the air compressor chamber via the air supply port and ii) an opened
10 position at which the supply valve opens the air supply port and thereby opens fluid
11 communication between the source of supply air and the air compressor chamber via
12 the air supply port;

13 an air pump piston positioned in the air compressor chamber and operable to
14 move between i) an expansion position at which the air compressor chamber reaches
15 its maximum volume and ii) a contraction position at which the air compressor
16 chamber reaches its minimum volume;

17 a combustion cell defining a variable-volume combustion chamber, separate
18 from the actuating fluid compressor chamber, an air [inlet]intake port, an exhaust
19 port, and an actuating fluid common rail, said air [inlet]intake port and exhaust port
20 each arranged in fluid communication with the combustion chamber;

21 an air storage chamber arranged in fluid communication between the air exit
22 port of the air compressor cell and the air intake port of the combustion cell;

23 an air check valve arranged in fluid communication between said air exit port
24 and the air storage chamber, said air check valve operable to allow only one-way
25 fluid flow from the air compressor chamber to the air storage chamber;

26 an actuating fluid compressor cell defining a variable-volume actuating fluid
27 compressor chamber and an actuating fluid port arranged in fluid communication
28 with the actuating fluid compressor chamber, said actuating fluid port adapted to
29 communicate with a source of actuating fluid;

30 an actuating fluid drain passage [adapted to be arranged in fluid
31 communication with the source of actuating fluid];

32 an actuating fluid supply valve arranged in fluid communication between the
33 source of actuating fluid and the actuating fluid port and selectively operable to

34 move between i) a closed position at which the supply valve closes fluid
35 communication between the source of actuating fluid and the actuating fluid
36 compressor chamber via the actuating fluid port and ii) an opened position at which
37 the supply valve opens fluid communication between the source of actuating fluid
38 and the actuating fluid compressor chamber via the actuating fluid port;

39 an actuating fluid pump piston positioned in the actuating fluid compressor
40 chamber and operable to move therein between i) an expansion position at which
41 the actuating fluid compressor chamber reaches its maximum volume and ii) a
42 contraction position at which the actuating fluid compressor chamber reaches its
43 minimum volume;

44 an actuating fluid storage chamber arranged in fluid communication between
45 the actuating fluid port of the actuating fluid compressor cell and the actuating fluid
46 common rail;

47 an actuating fluid check valve arranged in fluid communication between the
48 actuating fluid port of the actuating fluid compressor cell and the actuating fluid
49 storage chamber, said actuating fluid check valve operable to allow only one-way
50 fluid flow from the actuating fluid compressor chamber to the actuating fluid storage
51 chamber;

52 a hydraulically-actuatable intake valve associated with the air [inlet]intake
53 port of the combustion cell and having an actuating fluid chamber and a piston
54 portion positioned in the actuating fluid chamber, said intake valve selectively
55 operable to move between i) a closed position at which the intake valve closes the air
56 [inlet]intake port and thereby closes fluid communication between the air storage
57 chamber and the combustion chamber via the air [inlet]intake port and ii) an opened
58 position at which the intake valve opens the air [inlet]intake port and thereby opens
59 fluid communication between the air storage chamber and the combustion chamber
60 via the air [inlet]intake port;

61 an electronically-controllable magnetically-latchable first control valve
62 arranged in fluid communication between the actuating fluid common rail and the
63 actuating fluid chamber of the intake valve, said first control valve selectively
64 operable to move between i) a closed position at which the first control valve closes
65 fluid communication between the actuating fluid common rail and the actuating fluid

66 chamber of the intake valve and opens fluid communication between the actuating
67 fluid drain passage and the actuating fluid chamber of the intake valve thereby
68 allowing the intake valve to be moved towards its closed position and ii) an opened
69 position at which the first control valve opens fluid communication between the
70 actuating fluid common rail and the actuating fluid chamber of the intake valve and
71 closes fluid communication between the actuating fluid drain passage and the
72 actuating fluid chamber of the intake valve thereby allowing the intake valve to be
73 hydraulically moved towards its opened position ;

74 a hydraulically-actuatable exhaust valve associated with the exhaust port of
75 the combustion cell and having an actuating fluid chamber and a piston portion
76 positioned in the actuating fluid chamber, said exhaust valve selectively operable to
77 move between i) a closed position at which the exhaust valve closes the exhaust port
78 and thereby closes fluid communication between the combustion chamber and the
79 exhaust port and ii) an opened position at which the exhaust valve opens the exhaust
80 port and thereby opens fluid communication between the combustion chamber and
81 the exhaust port;

82 an electronically-controllable magnetically-latchable second control valve
83 arranged in fluid communication between the actuating fluid common rail and the
84 actuating fluid chamber of the exhaust valve, said second control valve selectively
85 operable to move between i) a closed position at which the second control valve
86 closes fluid communication between the actuating fluid common rail and the
87 actuating fluid chamber of the exhaust valve and opens fluid communication
88 between the actuating fluid drain passage and the actuating fluid chamber of the
89 exhaust valve thereby allowing the exhaust valve to be moved towards its closed
90 position and ii) an opened position at which the second control valve opens fluid
91 communication between the actuating fluid common rail and the actuating fluid
92 chamber of the exhaust valve and closes fluid communication between the actuating
93 fluid drain passage and the actuating fluid chamber of the exhaust valve thereby
94 allowing the exhaust valve to be hydraulically moved towards its opened position;
95 and

96 a power piston positioned in the combustion chamber and operable to move
97 therein between i) an expansion position at which the combustion chamber reaches

its maximum volume and ii) a contraction position at which the combustion chamber reaches its minimum volume.

30. The power module of claim 29, wherein said actuating fluid pump piston is driven by said air pump piston.

31. (Amended) A power module, comprising:
an air compressor cell defining a variable-volume air compressor chamber, an air supply port, and an air exit port, said air supply port and air exit port each arranged in separate fluid communication with the air compressor chamber, said air supply port adapted to communicate with a source of supply air;
an electronically-controllable magnetically-latchable air supply poppet valve associated with the air supply port, said air supply poppet valve including a magnetically-latchable poppet having an end portion and movable between a closed position and an opened position, a return spring operable to bias the poppet of the air supply poppet valve towards its closed position at which the poppet of the air supply poppet valve closes the air supply port and thereby closes fluid communication between the source of supply air and the air compressor chamber via the air supply port, and an opening-direction electrical coil located proximate the end portion of the poppet, said opening-direction electrical coil selectively operable to electromagnetically pull the poppet of the air supply poppet valve towards its opened position at which the poppet of the air supply poppet valve opens the air supply port and thereby opens fluid communication between the source of supply air and the air compressor chamber via the air supply port;
an air pump piston positioned in the air compressor chamber and operable to reciprocally move between i) an expansion position at which the air compressor chamber reaches its maximum volume and ii) a contraction position at which the air compressor chamber reaches its minimum volume;
a combustion cell defining a variable-volume internal combustion chamber, separate from the actuating fluid compressor chamber, an air [inlet]intake port, an exhaust port, and an actuating fluid common rail, said air [inlet]intake port and

exhaust port each arranged in separate fluid communication with the combustion chamber;

an air storage chamber arranged in fluid communication between the air exit port of the air compressor cell and the air intake port of the combustion cell;

an air check valve arranged in fluid communication between said air exit port and the air storage chamber, said air check valve operable to allow only one-way fluid flow from the air compressor chamber to the air storage chamber;

an actuating fluid compressor cell defining a variable-volume actuating fluid compressor chamber and an actuating fluid port arranged in fluid communication with the actuating fluid compressor chamber, said actuating fluid port adapted to communicate with a source of actuating fluid;

an actuating fluid drain passage [adapted to be arranged in fluid communication with the source of actuating fluid];

an electronically-controllable magnetically-latchable two-way actuating fluid supply valve arranged in fluid communication between the source of actuating fluid and the actuating fluid port, said actuating fluid supply valve including a magnetically-latchable spool having one end portion and an opposite end portion and movable between a closed position and an opened position, a closing-direction electrical coil located proximate the one end portion of the spool, and an opening-direction electrical coil located proximate the opposite end portion of the spool, said closing-direction electrical coil selectively operable to electromagnetically pull the spool of the actuating fluid supply valve towards its closed position at which the spool of the actuating fluid supply valve closes fluid communication between the source of actuating fluid and the actuating fluid compressor chamber via the actuating fluid port, said opening-direction electrical coil selectively operable to electromagnetically pull the spool of the actuating fluid supply valve towards its opened position at which the spool of the actuating fluid supply valve opens fluid communication between the source of actuating fluid and the actuating fluid compressor chamber via the actuating fluid port;

an actuating fluid pump piston positioned in the actuating fluid compressor chamber and operable to reciprocally move therein between i) an expansion position at which the actuating fluid compressor chamber reaches its maximum volume and

58 ii) a contraction position at which the actuating fluid compressor chamber reaches its
59 minimum volume;

60 an actuating fluid storage chamber arranged in fluid communication between
61 the actuating fluid port of the actuating fluid compressor cell and the actuating fluid
62 common rail;

63 an actuating fluid check valve arranged in fluid communication between the
64 actuating fluid port of the actuating fluid compressor cell and the actuating fluid
65 storage chamber, said actuating fluid check valve operable to allow only one-way
66 fluid flow from the actuating fluid compressor chamber to the actuating fluid storage
67 chamber;

68 a hydraulically-actuatable intake poppet valve associated with the air
69 [inlet]intake port of the combustion cell and having an actuating fluid chamber and a
70 piston portion positioned in the actuating fluid chamber, said intake poppet valve
71 selectively operable to reciprocally move between i) a closed position at which the
72 intake poppet valve closes the air [inlet]intake port and thereby closes fluid
73 communication between the air storage chamber and the combustion chamber via
74 the air [inlet]intake port and ii) an opened position at which the intake poppet valve
75 opens the air [inlet]intake port and thereby opens fluid communication between the
76 air storage chamber and the combustion chamber via the air [inlet]intake port;

77 an electronically-controllable magnetically-latchable three-way first control
78 valve arranged in fluid communication between the actuating fluid common rail and
79 the actuating fluid chamber of the intake valve, said first control valve including a
80 magnetically-latchable spool having one end portion and an opposite end portion and
81 movable between a closed position and an opened position, a closing-direction
82 electrical coil located proximate the one end portion of the spool, and an opening-
83 direction electrical coil located proximate the opposite end portion of the spool, said
84 closing-direction electrical coil selectively operable to electromagnetically pull the
85 spool towards its closed position at which the spool of the first control valve closes
86 fluid communication between the actuating fluid common rail and the actuating fluid
87 chamber of the intake poppet valve and opens fluid communication between the
88 actuating fluid drain passage and the actuating fluid chamber of the intake poppet
89 valve thereby allowing the intake poppet valve to be moved towards its closed

position, said opening-direction electrical coil selectively operable to electromagnetically pull the spool towards its opened position at which the spool of the first control valve opens fluid communication between the actuating fluid common rail and the actuating fluid chamber of the intake poppet valve and closes fluid communication between the actuating fluid drain passage and the actuating fluid chamber of the intake poppet valve thereby allowing the intake poppet valve to be hydraulically moved towards its opened position;

a hydraulically-actuatable exhaust poppet valve associated with the exhaust port of the combustion cell and having an actuating fluid chamber and a piston portion positioned in the actuating fluid chamber, said exhaust poppet valve selectively operable to reciprocally move between i) a closed position at which the exhaust poppet valve closes the exhaust port and thereby closes fluid communication between the combustion chamber and the exhaust port and ii) an opened position at which the exhaust poppet valve opens the exhaust port and thereby opens fluid communication between the combustion chamber and the exhaust port;

an electronically-controllable magnetically-latchable three-way second control valve arranged in fluid communication between the actuating fluid common rail and the actuating fluid chamber of the exhaust poppet valve, said second control valve including a magnetically-latchable spool having one end portion and an opposite end portion and movable between a closed position and an opened position, a closing-direction electrical coil located proximate the one end portion of the spool, and an opening-direction electrical coil located proximate the opposite end portion of the spool, said closing-direction electrical coil selectively operable to electromagnetically pull the spool towards its closed position at which the spool of the second control valve closes fluid communication between the actuating fluid common rail and the actuating fluid chamber of the exhaust poppet valve and opens fluid communication between the actuating fluid drain passage and the actuating fluid chamber of the exhaust poppet valve thereby allowing the exhaust poppet valve to be moved towards its closed position, said opening-direction electrical coil selectively operable to electromagnetically pull the spool towards its opened position at which the spool of the second control valve opens fluid communication between the actuating fluid common rail and the actuating fluid chamber of the exhaust

poppet valve and closes fluid communication between the actuating fluid drain passage and the actuating fluid chamber of the exhaust poppet valve thereby allowing the exhaust poppet valve to be hydraulically moved towards its opened position; and

a power piston positioned in the combustion chamber and operable to reciprocally move therein between i) an expansion position at which the combustion chamber reaches its maximum volume and ii) a contraction position at which the combustion chamber reaches its minimum volume.

32. (Amended) An internal combustion engine, comprising:

a plurality of power modules connected to generate work together wherein each power module separately includes an air compressor cell defining a variable-volume air compressor chamber, an air supply port, and an air exit port, said air supply port and air exit port each arranged in fluid communication with the air compressor chamber, said air supply port adapted to communicate with a source of supply air; an electronically-controllable magnetically-latchable air supply valve associated with the air supply port and selectively operable to move between i) a closed position at which the air supply valve closes the air supply port and thereby closes fluid communication between the source of supply air and the air compressor chamber via the air supply port and ii) an opened position at which the air supply valve opens the air supply port and thereby opens fluid communication between the source of supply air and the air compressor chamber via the air supply port; an air pump piston positioned in the air compressor chamber and operable to move between i) an expansion position at which the air compressor chamber reaches its maximum volume and ii) a contraction position at which the air compressor chamber reaches its minimum volume; a combustion cell defining a variable-volume combustion chamber separate from the air compressor chamber, an air intake port, [and] an exhaust port, and an actuating fluid common rail adapted to be arranged in fluid communication with a source of pressurized actuating fluid, said air intake port and exhaust port each arranged in fluid communication with the combustion chamber; an actuating fluid drain passage; an air storage chamber arranged in fluid communication between the air exit port of the air compressor cell and the air intake

port of the combustion cell; [an]a hydraulically-actuatable intake valve associated with the air intake port of the combustion cell and having an actuating fluid chamber and a piston portion positioned in the acting fluid chamber, said intake valve selectively operable to move between i) a closed position at which the intake valve closes the air intake port and thereby closes fluid communication between the air storage chamber and the combustion chamber via the air intake port and ii) an opened position at which the intake valve opens the air intake port and thereby opens fluid communication between the air storage chamber and the combustion chamber via the air intake port; an electronically-controllable magnetically-latchable first control valve arranged in fluid communication between the actuating fluid common rail and the actuating fluid chamber of the intake valve, said first control valve selectively operable to move between i) a closed position at which the first control valve closes fluid communication between the actuating fluid common rail and the actuating fluid chamber of the intake valve and opens fluid communication between the actuating fluid drain passage and the actuating fluid chamber of the intake valve thereby allowing the intake valve to be moved towards its closed position and ii) an opened position at which the first control valve opens fluid communication between the actuating fluid common rail and the actuating fluid chamber of the intake valve and closes fluid communication between the actuating fluid drain passage and the actuating fluid chamber of the intake valve thereby allowing the intake valve to be hydraulically moved towards its opened position; [an]a hydraulically-actuatable exhaust valve associated with the exhaust port of the combustion cell and having an actuating fluid chamber and a piston portion positioned in the actuating fluid chamber, said exhaust valve selectively operable to move between i) a closed position at which the exhaust valve closes the exhaust port and thereby closes fluid communication between the combustion chamber and the exhaust port and ii) an opened position at which the exhaust valve opens the exhaust port and thereby opens fluid communication between the combustion chamber and the exhaust port; an electronically-controllable magnetically-latchable second control valve arranged in fluid communication between the actuating fluid common rail and the actuating fluid chamber of the exhaust valve, said second control valve selectively operable to move between i) a closed position at which the second control valve closes fluid

56 communication between the actuating fluid common rail and the actuating fluid
57 chamber of the exhaust valve and opens fluid communication between the actuating
58 fluid drain passage and the actuating fluid chamber of the exhaust valve thereby
59 allowing the exhaust valve to be moved towards its closed position and ii) an opened
60 position at which the second control valve opens fluid communication between the
61 actuating fluid common rail and the actuating fluid chamber of the exhaust valve and
62 closes fluid communication between the actuating fluid drain passage and the
63 actuating fluid chamber of the exhaust valve thereby allowing the exhaust valve to
64 be hydraulically moved towards its opened position; and a power piston positioned
65 in the respective combustion chamber and operable to move therein between i) an
66 expansion position at which the respective combustion chamber reaches its
67 maximum volume and ii) a contraction position at which the respective combustion
68 chamber reaches its minimum volume; wherein said air compressor chamber and air
69 storage chamber of each power module are isolated from fluid communication and
70 independently operable with respect to the air compressor chamber and air storage
71 chamber of any other said power module of the internal combustion engine.
72

1 33. [The internal combustion engine of claim 32] (Amended) An internal
2 combustion engine, comprising:

3 a plurality of power modules connected to generate work together wherein
4 each power module separately includes an air compressor cell defining a variable-
5 volume air compressor chamber, an air supply port, and an air exit port, said air
6 supply port and air exit port each arranged in fluid communication with the air
7 compressor chamber, said air supply port adapted to communicate with a source of
8 supply air; an air supply valve associated with the air supply port and selectively
9 operable to move between i) a closed position at which the air supply valve closes
10 the air supply port and thereby closes fluid communication between the source of
11 supply air and the air compressor chamber via the air supply port and ii) an opened
12 position at which the air supply valve opens the air supply port and thereby opens
13 fluid communication between the source of supply air and the air compressor
14 chamber via the air supply port; an air pump piston positioned in the air compressor
15 chamber and operable to move between i) an expansion position at which the air

compressor chamber reaches its maximum volume and ii) a contraction position at which the air compressor chamber reaches its minimum volume; a combustion cell defining a variable-volume combustion chamber separate from the air compressor chamber, an air intake port, and an exhaust port, said air intake port and exhaust port each arranged in fluid communication with the combustion chamber; an air storage chamber arranged in fluid communication between the air exit port of the air compressor cell and the air intake port of the combustion cell; an intake valve associated with the air intake port of the combustion cell and selectively operable to move between i) a closed position at which the intake valve closes the air intake port and thereby closes fluid communication between the air storage chamber and the combustion chamber via the air intake port and ii) an opened position at which the intake valve opens the air intake port and thereby opens fluid communication between the air storage chamber and the combustion chamber via the air intake port; an exhaust valve associated with the exhaust port of the combustion cell and selectively operable to move between i) a closed position at which the exhaust valve closes the exhaust port and thereby closes fluid communication between the combustion chamber and the exhaust port and ii) an opened position at which the exhaust valve opens the exhaust port and thereby opens fluid communication between the combustion chamber and the exhaust port; and a power piston positioned in the respective combustion chamber and operable to move therein between i) an expansion position at which the respective combustion chamber reaches its maximum volume and ii) a contraction position at which the respective combustion chamber reaches its minimum volume; wherein said air compressor chamber and air storage chamber of each power module are isolated from fluid communication and independently operable with respect to the air compressor chamber and air storage chamber of any other said power module of the internal combustion engine, further including a separate electronic control unit associated with each power module, each electronic control unit operable to selectively and independently control the operation of the respective air supply valve with digital pulses of electrical current.

1 34. The internal combustion engine of claim 33, further including an air
2 pressure sensor associated with each power module, said air pressure sensor operable
3 to sense the pressure of air in the respective air storage chamber and provide the
4 respective electronic control unit with a signal indicative of such pressure, said
5 respective electronic control unit operable to move the respective air supply valve to
6 its opened position in response to said pressure being below a threshold air pressure,
7 said respective electronic control unit operable to move the respective air supply
8 valve to its closed position in response to said pressure being at least the threshold
9 air pressure.

10
1 35. [The internal combustion of claim 32] (Amended) An internal
2 combustion engine, comprising:
3 a plurality of power modules connected to generate work together wherein
4 each power module separately includes an air compressor cell defining a variable-
5 volume air compressor chamber, an air supply port, and an air exit port, said air
6 supply port and air exit port each arranged in fluid communication with the air
7 compressor chamber, said air supply port adapted to communicate with a source of
8 supply air; an air supply valve associated with the air supply port and selectively
9 operable to move between i) a closed position at which the air supply valve closes
10 the air supply port and thereby closes fluid communication between the source of
11 supply air and the air compressor chamber via the air supply port and ii) an opened
12 position at which the air supply valve opens the air supply port and thereby opens
13 fluid communication between the source of supply air and the air compressor
14 chamber via the air supply port; an air pump piston positioned in the air compressor
15 chamber and operable to move between i) an expansion position at which the air
16 compressor chamber reaches its maximum volume and ii) a contraction position at
17 which the air compressor chamber reaches its minimum volume; a combustion cell
18 defining a variable-volume combustion chamber separate from the air compressor
19 chamber, an air intake port, and an exhaust port, said air intake port and exhaust port
20 each arranged in fluid communication with the combustion chamber; an air storage
21 chamber arranged in fluid communication between the air exit port of the air
22 compressor cell and the air intake port of the combustion cell; an intake valve

23 associated with the air intake port of the combustion cell and selectively operable to
24 move between i) a closed position at which the intake valve closes the air intake port
25 and thereby closes fluid communication between the air storage chamber and the
26 combustion chamber via the air intake port and ii) an opened position at which the
27 intake valve opens the air intake port and thereby opens fluid communication
28 between the air storage chamber and the combustion chamber via the air intake port;
29 an exhaust valve associated with the exhaust port of the combustion cell and
30 selectively operable to move between i) a closed position at which the exhaust valve
31 closes the exhaust port and thereby closes fluid communication between the
32 combustion chamber and the exhaust port and ii) an opened position at which the
33 exhaust valve opens the exhaust port and thereby opens fluid communication
34 between the combustion chamber and the exhaust port; and a power piston
35 positioned in the respective combustion chamber and operable to move therein
36 between i) an expansion position at which the respective combustion chamber
37 reaches its maximum volume and ii) a contraction position at which the respective
38 combustion chamber reaches its minimum volume; wherein said air compressor
39 chamber and air storage chamber of each power module are isolated from fluid
40 communication and independently operable with respect to the air compressor
41 chamber and air storage chamber of any other said power module of the internal
42 combustion engine, wherein each control unit is operable to selectively and
43 independently control the operation of the respective air supply valve in response to
44 at least one sensed parameter selected from the group of air temperature, air
45 manifold pressure, actuating fluid temperature, actuating fluid pressure, barometric
46 pressure, throttle position, power piston position, engine brake signals, starter inputs,
47 and ignition switch position.
48

1 36. The internal combustion engine of claim 32, wherein the air
2 compressor cell and combustion cell of each power module are located adjacent to
3 one another.
4

1 37. The internal combustion engine of claim 32, wherein said power
2 modules are arranged substantially in-line relative to one another.

3
1 38. The internal combustion engine of claim 32, wherein the air
2 compressor cells are arranged in an alternating and substantially in-line pattern with
3 respect to the combustion cells.
4

1 39. (Amended) An internal combustion engine, comprising:
2 a plurality of power modules connected to generate work together wherein each
3 power module separately includes an actuating fluid compressor cell defining a
4 variable-volume actuating fluid compressor chamber and an actuating fluid port
5 arranged in fluid communication with the actuating fluid compressor chamber, said
6 actuating fluid port adapted to communicate with a source of actuating fluid; an
7 actuating fluid drain passage [adapted to be arranged in fluid communication with
8 the source of actuating fluid]; an actuating fluid supply valve arranged in fluid
9 communication between the source of actuating fluid and the actuating fluid port and
10 selectively operable to move between i) a closed position at which the supply valve
11 closes fluid communication between the source of actuating fluid and the actuating
12 fluid compressor chamber via the actuating fluid port and ii) an opened position at
13 which the supply valve opens fluid communication between the source of actuating
14 fluid and the actuating fluid compressor chamber via the actuating fluid port; an
15 actuating fluid pump piston positioned in the actuating fluid compressor chamber
16 and operable to move therein between i) an expansion position at which the
17 actuating fluid compressor chamber reaches its maximum volume and ii) a
18 contraction position at which the actuating fluid compressor chamber reaches its
19 minimum volume; a combustion cell defining a variable-volume combustion
20 chamber, separate from the actuating fluid compressor chamber, an air [inlet]intake
21 port, an exhaust port, and an actuating fluid common rail, said air [inlet]intake port
22 and exhaust port each arranged in fluid communication with the combustion
23 chamber; an actuating fluid storage chamber arranged in fluid communication
24 between the actuating fluid port of the actuating fluid compressor cell and the
25 actuating fluid common rail; a hydraulically-actuatable intake valve associated with
26 the air [inlet]intake port of the combustion cell and having an actuating fluid
27 chamber and a piston portion positioned in the actuating fluid chamber, said intake

28 valve selectively operable to move between i) a closed position at which the intake
29 valve closes the air [inlet]intake port and thereby closes fluid communication
30 between the air storage chamber and the combustion chamber via the air
31 [inlet]intake port and ii) an opened position at which the intake valve opens the air
32 [inlet]intake port and thereby opens fluid communication between the air storage
33 chamber and the combustion chamber via the air [inlet]intake port; an electronically-
34 controllable magnetically-latchable first control valve arranged in fluid
35 communication between the actuating fluid common rail and the actuating fluid
36 chamber of the intake valve, said first control valve selectively operable to move
37 between i) a closed position at which the first control valve closes fluid
38 communication between the actuating fluid common rail and the actuating fluid
39 chamber of the intake valve and opens fluid communication between the actuating
40 fluid drain passage and the actuating fluid chamber of the intake valve thereby
41 allowing the intake valve to be moved towards its closed position and ii) an opened
42 position at which the first control valve opens fluid communication between the
43 actuating fluid common rail and the actuating fluid chamber of the intake valve and
44 closes fluid communication between the actuating fluid drain passage and the
45 actuating fluid chamber of the intake valve thereby allowing the intake valve to be
46 hydraulically moved towards its opened position; a hydraulically-actuatable exhaust
47 valve associated with the exhaust port of the combustion cell and having an
48 actuating fluid chamber and a piston portion positioned in the actuating fluid
49 chamber, said exhaust valve selectively operable to move between i) a closed
50 position at which the exhaust valve closes the exhaust port and thereby closes fluid
51 communication between the combustion chamber and the exhaust port and ii) an
52 opened position at which the exhaust valve opens the exhaust port and thereby opens
53 fluid communication between the combustion chamber and the exhaust port; an
54 electronically-controllable magnetically-latchable second control valve arranged in
55 fluid communication between the actuating fluid common rail and the actuating fluid
56 chamber of the exhaust valve, said second control valve selectively operable to move
57 between i) a closed position at which the second control valve closes fluid
58 communication between the actuating fluid common rail and the actuating fluid
59 chamber of the exhaust valve and opens fluid communication between the actuating

60 fluid drain passage and the actuating fluid chamber of the exhaust valve thereby
61 allowing the exhaust valve to be moved towards its closed position and ii) an opened
62 position at which the second control valve opens fluid communication between the
63 actuating fluid common rail and the actuating fluid chamber of the exhaust valve and
64 closes fluid communication between the actuating fluid drain passage and the
65 actuating fluid chamber of the exhaust valve thereby allowing the exhaust valve to
66 be hydraulically moved towards its opened position; and a power piston positioned
67 in the combustion chamber and operable to move therein between i) an expansion
68 position at which the combustion chamber reaches its maximum volume and ii) a
69 contraction position at which the combustion chamber reaches its minimum volume;
70 wherein said actuating fluid compressor chamber and actuating fluid storage
71 chamber of each power module are isolated from fluid communication and
72 independently operable with respect to the actuating fluid compressor chamber and
73 actuating fluid storage chamber of any other said power module of the internal
74 combustion engine.

75
1 40. The internal combustion engine of claim 39, wherein said
2 actuating fluid compressor cell and combustion cell of each power module are
3 located adjacent to one another.

4
1 41. The internal combustion engine of claim 39, wherein said power
2 modules are arranged substantially in-line relative to one another.

3
1 42. The internal combustion engine of claim 39, wherein the actuating
2 fluid compressor cells are arranged in an alternating and substantially in-line pattern
3 with respect to the combustion cells.

4
1 43. (Amended) A two-stroke cycle power module, comprising:
2 a rotatable crankshaft;
3 a combustion chamber;
4 an actuating fluid drain passage;

5 an actuating fluid common rail adapted to be arranged in fluid
6 communication with a source of pressurized actuating fluid;

7 a movable power piston positioned in the combustion chamber and
8 coupled to the crankshaft for movement therewith;

9 [an electronically-controllable hydraulically-actuatable fuel injector
10 extending into the combustion chamber and selectively operable to inject fuel
11 therein;]

12 an electronically-controllable hydraulically-actuatable intake valve having an
13 actuating fluid chamber and a piston portion positioned in the actuating fluid
14 chamber, said intake valve selectively operable to admit air into the combustion
15 chamber;

16 an electronically-controllable magnetically-latchable first control valve
17 arranged in fluid communication between the actuating fluid common rail and the
18 actuating fluid chamber of the intake valve, said first control valve selectively
19 operable to move between i) a closed position at which the first control valve closes
20 fluid communication between the actuating fluid common rail and the actuating fluid
21 chamber of the intake valve and opens fluid communication between the actuating
22 fluid drain passage and the actuating fluid chamber of the intake valve thereby
23 allowing the intake valve to be moved towards its closed position and ii) an opened
24 position at which the first control valve opens fluid communication between the
25 actuating fluid common rail and the actuating fluid chamber of the intake valve and
26 closes fluid communication between the actuating fluid drain passage and the
27 actuating fluid chamber of the intake valve thereby allowing the intake valve to be
28 hydraulically moved towards its opened position; [and]

29 an electronically-controllable hydraulically-actuatable exhaust valve having
30 an actuating fluid chamber and a piston portion positioned in the actuating fluid
31 chamber, said exhaust valve selectively operable to vent exhaust gas from the
32 combustion chamber;

33 an electronically-controllable magnetically-latchable second control valve
34 arranged in fluid communication between the actuating fluid common rail and the
35 actuating fluid chamber of the exhaust valve, said second control valve selectively
36 operable to move between i) a closed position at which the second control valve

closes fluid communication between the actuating fluid common rail and the
actuating fluid chamber of the exhaust valve and opens fluid communication
between the actuating fluid drain passage and the actuating fluid chamber of the
exhaust valve thereby allowing the exhaust valve to be moved towards its closed
position and ii) an opened position at which the second control valve opens fluid
communication between the actuating fluid common rail and the actuating fluid
chamber of the exhaust valve and closes fluid communication between the actuating
fluid drain passage and the actuating fluid chamber of the exhaust valve thereby
allowing the exhaust valve to be hydraulically moved towards its opened position
an electronically-controllable hydraulically-actuatable fuel injector
extending into the combustion chamber and selectively operable to inject fuel
therein, wherein said injector includes an actuating fluid chamber, a piston portion
positioned in the actuating fluid chamber, a check valve movable between a closed
position at which the check valve blocks injection of fuel and an opened position at
which the check valve opens injection of fuel, and an electronically-controllable
magnetically-latchable third control valve arranged in fluid communication between
the actuating fluid common rail and the actuating fluid chamber of the injector, said
third control valve selectively operable to move between i) a closed position at
which the third control valve closes fluid communication between the actuating fluid
common rail and the actuating fluid chamber of the injector and opens fluid
communication between the actuating fluid drain passage and the actuating fluid
chamber of the injector thereby allowing the check valve of the injector to be moved
towards its closed position and ii) an opened position at which the third control
valve opens fluid communication between the actuating fluid common rail and the
actuating fluid chamber of the injector and closes fluid communication between the
actuating fluid drain passage and the actuating fluid chamber of the injector thereby
allowing the check valve to be hydraulically moved towards its opened position,
wherein said crankshaft is selectively rotatable in one angular direction and a reverse
angular direction in response to selectable timing and sequence of operation of the
intake and exhaust valves and the fuel injector relative to the position of the power
piston.

1 44. A method of operating a two-stroke cycle power module having a
2 rotatable crankshaft; an air compressor cell defining a variable-volume air
3 compressor chamber, an air supply port, and an air exit port, said air supply port and
4 air exit port each arranged in fluid communication with the air compressor chamber,
5 said air supply port adapted to communicate with a source of supply air; an air
6 supply valve associated with the air supply port and selectively operable to move
7 between i) a closed position at which the air supply valve closes the air supply port
8 and thereby closes fluid communication between the source of supply air and the air
9 compressor chamber via the air supply port and ii) an opened position at which the
10 air supply valve opens the air supply port and thereby opens fluid communication
11 between the source of supply air and the air compressor chamber via the air supply
12 port; an air pump piston positioned in the air compressor chamber and operable to
13 move between i) an expansion position at which the air compressor chamber reaches
14 its maximum volume and ii) a contraction position at which the air compressor
15 chamber reaches its minimum volume; a combustion cell defining a variable-volume
16 combustion chamber separate from the air compressor chamber, an air intake port,
17 and an exhaust port, said air intake port and exhaust port each arranged in fluid
18 communication with the combustion chamber; an air storage chamber arranged in
19 fluid communication between the air exit port of the air compressor cell and the air
20 intake port of the combustion cell; an intake valve associated with the air intake port
21 of the combustion cell and selectively operable to move between i) a closed position
22 at which the intake valve closes the air intake port and thereby closes fluid
23 communication between the air storage chamber and the combustion chamber via
24 the air intake port and ii) an opened position at which the intake valve opens the air
25 intake port and thereby opens fluid communication between the air storage chamber
26 and the combustion chamber via the air intake port; an exhaust valve associated with
27 the exhaust port of the combustion cell and selectively operable to move between i)
28 a closed position at which the exhaust valve closes the exhaust port and thereby
29 closes fluid communication between the combustion chamber and the exhaust port
30 and ii) an opened position at which the exhaust valve opens the exhaust port and
31 thereby opens fluid communication between the combustion chamber and the
32 exhaust port; and a power piston positioned in the combustion chamber and coupled

33 to the crankshaft for movement therewith, said power piston operable to move in the
34 combustion chamber between i) an expansion position at which the combustion
35 chamber reaches its maximum volume corresponding to a 180° angular position of
36 the crankshaft and ii) a contraction position at which the combustion chamber
37 reaches its minimum volume corresponding to a 0° angular position of the
38 crankshaft, said method comprising the steps of:

39 moving the power piston from its contraction position and towards its
40 expansion position;

41 opening the exhaust valve when the power piston has been moved to a first
42 position corresponding to a first angular position of the crankshaft;

43 opening the intake valve when the power piston has been moved to a second
44 position corresponding to a second angular position of the crankshaft;

45 moving the power piston to its expansion position;

46 moving the power piston from its expansion position and towards its
47 contraction position;

48 closing the exhaust valve when the power piston has been moved to a third
49 position corresponding to a third angular position of the crankshaft;

50 closing the intake valve when the power piston has been moved to a fourth
51 position corresponding to a fourth angular position of the crankshaft; and

52 moving the power piston to its contraction position.
53

1 45. The method of claim 44, wherein the angular distance between the
2 first and fourth angular positions is about 80° .
3

1 46. The method of claim 44, wherein the first angular position of the
2 crankshaft is about 140° , the second angular position of the crankshaft is about 160° ,
3 the third angular position of the crankshaft is about 200° , and the fourth angular
4 position of the crankshaft is about 220° .
5

1 47. The method of claim 44, wherein during operation of the power
2 module the combustion chamber has a peak fluid pressure of about 13,790 kPa
3 (about 2000 psi) when the power piston is at its contraction position.

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48. The method of claim 44, wherein during operation of the power module the combustion chamber has a residual fluid pressure greater than atmospheric pressure when the power piston is at its expansion position.

49. The method of claim 48, wherein the residual fluid pressure in the combustion chamber is at least about 138 kPa (about 20 psi).

50. (Amended) The method of claim [50]48, wherein the residual fluid pressure in the combustion chamber is in the range of about 138 to 207 kPa (about 20 to 30 psi).

CONCLUSION

In view of the amendments and remarks made above, it is respectfully submitted that the pending claims 1-50 are in condition for allowance, and such action is respectfully solicited.

Respectfully submitted,



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